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Conspicuity Comparison of Current and Proposed U.S. Army Wire Marker Designs

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In-flight wire strikes are a serious threat to U.S. Army aviation during all-weather daytime and nighttime helicopter operations. To reduce this threat, the aviation training community employs a passive marking system for increasing the conspicuity of high tension cables, electrical power lines, and telephone wires. This system uses international-orange fiberglass spheres having a diameter of approximately 11.5 inches and utilizing various conspicuity enhancing schemes. These spheres are attached to the cables and wires at locations heavily used by aircraft. In this study, the conspicuity of the basic and proposed modified designs was investigated as a function of background, illumination level (for both day and night with weather effects), sun (or other bright source) angle, and viewing system (e.g., unaided eye, thermal sensor, or image intensifier). While no differences among designs were observed under daylight conditions, improved performance under

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several viewing/lighting conditions was observed for two retroreflective polyhedron designs under typical aircraft lighting conditions at night. Increased detection ranges were noted both with and without image intensification devices and under aircraft lighting conditions characteristic of the local aviation training environment.

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Introduction

In-flight wire strikes are a serious threat to U.S. Army aviation during all-weather daytime and nighttime helicopter operations, including: terrain flight, enclosed area takeoff and landing, and confined area maneuvering. Despite training on wire avoidance techniques, peacetime wire strikes and the resultant loss of aircraft and life remain a serious problem. Previous investigations of rotary wing wire strike accidents for the periods of 1958-1965 (U. S. Army Aviation Materiel Laboratories, 1966), June 1966-June 1970 (Christian and Kuhns, 1971), July 1972-July 1976 (Mynard, 1977), and January 1974-August 1981 (Posey, et al., 1989) have shown a total of 553 wire strikes, resulting in 118 fatalities, and damage in excess of $40 million (these figures do not include the U.S. flying experience in Vietnam). Wire strike data since 1981 have not been tabulated. Inasmuch as a majority of mishaps have occurred during training and over familiar sites, it can be assumed the wire impact threat posed by combat operations in unfamiliar areas will increase.

The aviation training community at Fort Rucker, Alabama employs a passive marking system for increasing the conspicuity of high tension cables, electrical power lines, and telephone wires. This system uses international-orange fiberglass spheres having a diameter of approximately 11.5 inches. These spheres are attached to the cables and wires at locations heavily used by aircraft (Figure 1). Modification to the basic design consists of the application of 1-1/2 inch wide white high-reflective tape in a cross pattern. The conspicuity of the basic and modified designs varies as a function of background, illumination level (for both day and night with weather effects), sun (or other bright source) angle, and viewing system (e.g., unaided eye, thermal sensor, or image intensifier).

A proposed alternative marking system design has been submitted to the Army. This new design is a molded international-orange polyhedron with circular (2-1/2 inch diameter) patterns of 3M Scotchlite™ reflective sheeting applied to the individual faces of the polyhedron (Figure 2). This sheeting, similar to that used on civilian traffic control signs, consists of prismatic lenses which are formed in a transparent synthetic resin, sealed, and backed with a pressure-sensitive adhesive. The sheeting design uses the principle of retroreflection to increase the wire marker's conspicuity.

The Aviation Training Battalion (ATB), Fort Rucker, Alabama requested USAARL to compare performance between the current and proposed wire marking systems.

Figure 1. Current wire marker, international-orange sphere.

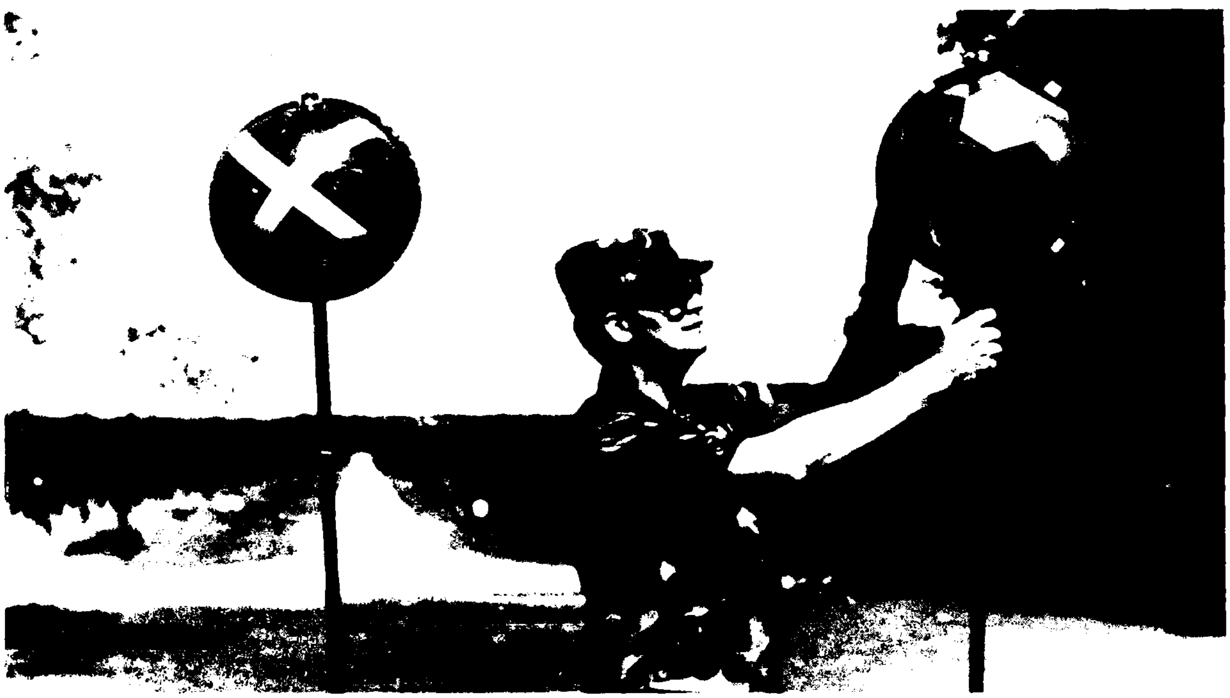


Figure 2. Marker enhancements include: (a) white reflective tape in cross-pattern (left) and (b) proposed polyhedron design with circular patterns of retroreflective sheeting material (right).

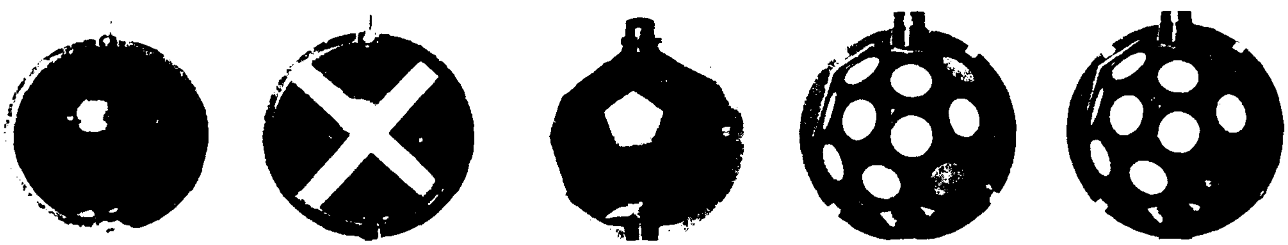
Methods

Subjects

Sixteen volunteer subjects, aged from 19-33 (average = 24.8), participated in the study. All participants were warrant officer candidates awaiting the start of helicopter flight training. All had passed the Army's Class I flight physical requiring at least 20/20 or better uncorrected Snellen acuity and normal color vision. Four subjects served as aeroscout observers (military occupational specialty 93B) and had previous experience with the AN/PVS-5 night vision goggle. The remaining subjects had no previous helicopter flight time or goggle experience.

Wire markers

Five wire marker designs, all international-orange in color, were tested. The designs were: (1) uniform sphere, (2) sphere with white reflective tape in a cross (X) pattern, (3) uniform polyhedron, (4) polyhedron with circular patterns of white retroreflective sheeting, and (5) polyhedron with circular patterns of yellow retroreflective sheeting. Each of the polyhedrons were of the same shape with flat polygonal faces on their outer surfaces. The designs included the two basic design



(a) (b) (c) (d) (e)

Figure 3. Wire marker test designs: (a) uniform sphere, (b) sphere with light reflective tape in a cross (X) design, (c) uniform polyhedron, (d) polyhedron with circular patterns of white retroreflective sheeting, (e) polyhedron with circular patterns of yellow retroreflective sheeting.

Figure 4. Wire marker mounted on pole.

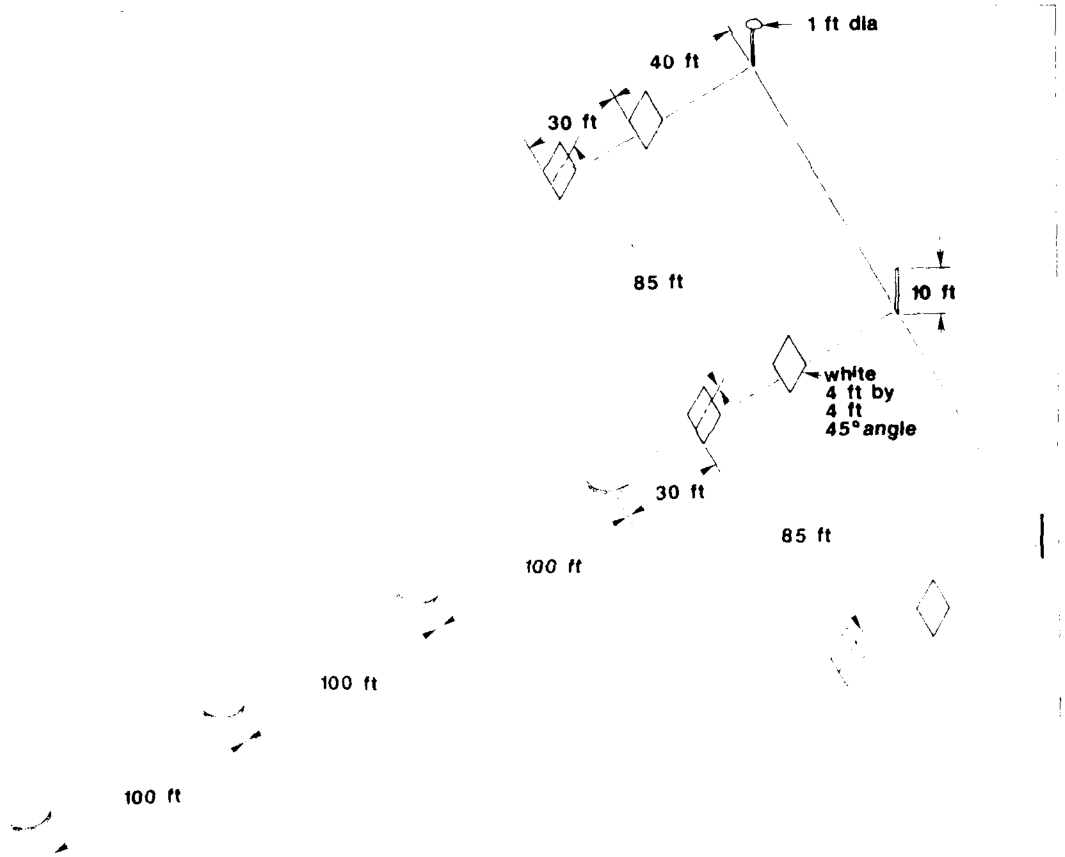


Figure 5. Schematic drawing of test field.

geometries (markers 1,3) and enhanced (reflective) versions of each (markers 2,4,5). The markers, shown in Figure 3, were provided by ATB.

Procedure

The study was conducted in two phases at Skelly stagefield near Opp, Alabama. In the first phase, the conspicuity of the wire marker designs was investigated under clear and sunny daytime conditions for the unaided eye with both the clear (class 1) and tinted (class 2) SPH-4 visors. Testing was accomplished for two sun angles representing the positions of oblique morning (0800-0900 hours) and overhead afternoon (1300-1400 hours) light. The second phase was conducted at night (2100-2400) for the unaided eye and with the AN/PVS-5 Night Vision Goggles (NVG) and the Aviator's Night Vision Imaging System (ANVIS) image intensification systems. Each nighttime viewing condition was tested under a number of different aircraft lighting conditions (see below). Nighttime trials were conducted under clear weather and lunar conditions of altitude greater than 30 degrees and fraction of illumination greater than 23 percent. A matrix of all the conditions tested is shown in Table 1.

In both phases, the wire markers were mounted on 10-foot poles located at the southern end of the stagefield (Figure 4); a tree line located behind the markers served as a relatively uniform, unstructured background. In the daytime, the poles were arranged in a single row at separation distances of 85 feet; at night, the distance between the poles was reduced to 50 feet. A pair of 4 X 4 foot wood panels, painted white and angled 45 degrees, were each positioned, in line, 40 feet and 70 feet, respectively, in front of each pole. These were used as lane markers to assist the subjects in identifying the target positions from the aircraft (see below). (At night, chemical light sticks were hung over each panel to facilitate identifying their location.) From the center pole, a series of automobile tires, painted white, were placed at intervals of 100 feet out to a distance of 4200 feet (the maximum available working range of the stagefield). These served both as observation points for the subjects viewing the markers and as references points for the pilots flying the aircraft. A schematic drawing of the test field is shown in Figure 5.

The subjects viewed the markers while seated sideways in either the left or right rear seats of the UH-1 helicopter. Subjects were tested four at a time, two on each side of the aircraft (Seats 3 and 6 on the right and Seats 2 and 5 on the left as shown in the UH-1 alternate seating plan [Department of the Army Technical Manual 55-1520-210-10] (Figure 6). During testing, the aircraft was maintained at a low hover (10-20 feet above ground level (AGL)) and subjects viewed downrange via the open cargo doors. To ensure an unobstructed view, trials were conducted with the aircraft turned 90 degrees left or right along an axis perpendicular to the markers.

Table 1

Test design matrix.

Target configuration	Test conditions						
	Daytime				Nighttime		
	Naked eye		Tinted visor		Naked eye	NVG	ANVIS
	Sun angle 1	Sun angle 2	Sun angle 1	Sun angle 2	Note 1	Note 2	
Uniform sphere	X	X	X	X	X	X	X
Sphere with cross pattern	X	X	X	X	X	X	X
Uniform polyhedron	X	X	X	X	X	X	X
Polyhedron w/ white retro-reflectors	X	X	X	X	X	X	X
Polyhedron w/ yellow retro-reflectors	X	X	X	X	X	X	X

Note 1 -- Aircraft lighting conditions: Unaided
(1) Position lights steady bright
(2) Anticollision light and position lights steady bright
(3) Search light and position lights steady bright
(4) No lights ("blackout")

Note 2 -- Aircraft lighting conditions: AN/PVS-5 and ANVIS
(1) Position lights steady dim
(2) Searchlight with "pink" filter
(3) No lights ("blackout")

Daylight trials

A detection threshold paradigm was selected to determine the relative conspicuity of each marker design under daylight

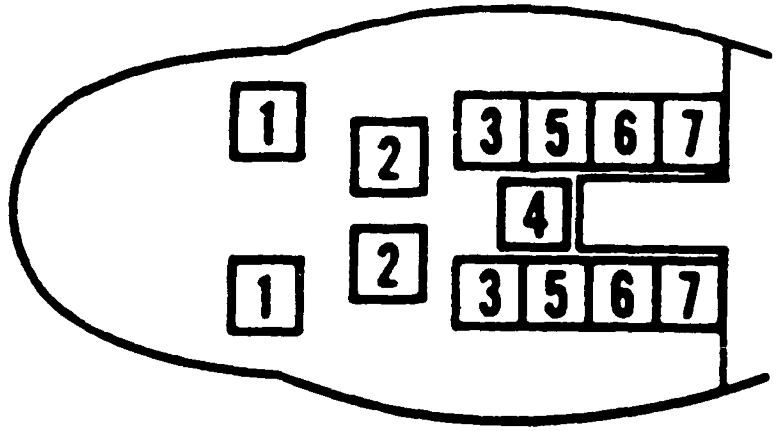


Figure 6. Subject seating in UH-1 test aircraft.

conditions. Thresholds were determined using an ascending method of limits together with a three-alternative forced choice procedure. On each trial, the target array consisted of a single marker design sample and two empty poles. The subject's task was to indicate on a data collection form the correct position of the marker -- left, center, or right. A data collector, seated between each pair of subjects (Seat 3; see Figure 6), monitored subject responses and communicated instructions to the pilots. Response feedback was not provided to the subjects.

As noted previously, daylight tests were conducted under two ambient lighting conditions comprising two different sun angles -- morning (oblique sun angle) and afternoon (direct overhead sun). Trials began at the maximum viewing distance of 4200 feet. After each response, the distance to the target was reduced by 100 feet and the trial continued. At each observation point, the aircraft hover was directed right and left accordingly, and subjects, one side at a time, were permitted a maximum of 10 seconds to indicate the target's position. (Subject viewing order [right side/left side of aircraft] was alternated with each trial.) Following the subjects' response, the aircraft hover-taxied to the next observation point and the trial resumed.

Both the wire marker and its initial pole position was varied randomly and exhaustively on each trial. Marker positions (left, center, or right) also varied randomly as the aircraft proceeded from one observation point to the next. For a given trial, detection range was defined as the (longest) range associated with the <u>first</u> of <u>three</u> consecutive correct responses. At any point, an incorrect response recycled the three-in-a-row correct response criterion. Three trials were run for each marker design, yielding a total of 30 trials (15 per sun angle) for each subject. For each marker, the subject's overall detection range was calculated as the average of the three trials.

Testing for each subject was conducted over a 2-day period. On the morning of day-1, two subjects were tested with each visor -- clear or tinted. Visors then were switched among the subjects for the afternoon run. On day-2, visor wear was reversed. Subjects wearing either clear or tinted visors on the previous morning's test now wore the opposite visor on the morning of day-2. The visors were then reversed again on the afternoon of day-2. A total of four subjects were tested under each visor/sun angle condition except for the tinted visor under sun angle 1 in which three subjects were tested.

Nighttime trials

Because of the reduced ranges associated with low-light viewing (for both pilots and subjects), several of the daytime test procedures were modified to enhance safety of flight. First, a modified <u>descending</u> method of limits was used to determine detection threshold. Second, observations began at a distance where the marker was known to be visible (under some viewing conditions, as close as 100 feet). Third, only two of the poles (marker lanes) -- center and right -- were used. The general procedure was as follows: On each trial, the test marker appeared on the right pole (from the subject's perspective) while a standard, comparison marker (the polyhedron with yellow reflective sheeting) appeared in the center. (During preliminary testing, this latter marker had the longest naked eye detection range. During actual testing, it was used primarily to orient the subjects gaze toward the test area. In addition, its identity remained unknown to the subjects and its threshold detection range was determined only while situated in the right [test] lane.) The subject's task consisted of indicating whether the right, left, both, or neither of the markers were visible. As before, succeeding observations were made at 100-foot intervals. However, instead of approaching the target, the aircraft moved away from the target with each observation. Detection threshold for each design was defined as the <u>last</u> distance at which the marker was reported visible. Because of the reduced pace of testing at night, only one trial per subject was run for each viewing/lighting combination.

As shown in Table 1, each viewing mode was run under several different aircraft lighting schemes. For <u>unaided</u> viewing, testing was conducted under four aircraft lighting conditions, including: (1) position ("running") lights steady bright;

(2) anticollision lights and position lights steady bright; (3) searchlight and position lights steady bright. For both the unaided and aided trials, the searchlight was turned on and rotated by the right-seat pilot 90 degrees right or left as the aircraft hovered perpendicular to (and the subjects faced) the targets. Targets were exposed by the beam for approximately 5 seconds; accurate target exposure was verified by the pilot either naked eye or with an ANVIS tube when the pink filter was used (see below). For <u>aided</u> viewing, three aircraft lighting schemes were employed: (1) position light steady dim; (2) searchlight with "pink" filter; and (3) no lights ("blackout"). Testing was conducted over a period of two nights -- unaided on night-1 and aided on night-2 with subjects tested four at a time. A total of eight subjects were tested under unaided conditions and four each with AN/PVS-5 and ANVIS image intensification devices. Threshold detection ranges for each marker were calculated as the mean detection range of each group. Separate detection thresholds were determined for each viewing/lighting condition combination.

<u>Results</u>

Daylight trials

Testing under both daylight conditions resulted in "ceiling" effects. Nearly all subjects, wearing either clear or tinted visors, reliably could detect the positions of each of the markers at the maximum (4200 feet) available range. These results are shown in Table 2.

Nighttime trials

Table 3 shows the results for the nighttime unaided viewing conditions. For the standard lighting configurations (position lights alone or anticollision lights in combination with position lights), the reflective polyhedron designs (markers 4 and 5) provided the longest detection ranges. Marker 2, the sphere with the reflective cross pattern, while superior to either baseline design, provided only 20-44 percent of the detection range of Markers 4 and 5. With the searchlight on, the enhanced designs were clearly superior to both baseline markers. However, as in the case of the daylight trials, ceiling effects precluded detection of differences between any of the reflective designs. Under blackout conditions, where the sources of illumination were limited to the moon and artificial ambient lighting, detection ranges were reduced markedly (and nearly equivalent) with each design.

Table 2

Mean (and standard deviation) detection ranges under daylight conditions (in feet).

Wire marker*	Sun angle 1		Sun angle 2	
	Clear visor N=4	Tinted visor N=3	Clear visor N=4	Tinted visor N=4
1	4200 (0)	4189 (20)	4175 (50)	4150 (58)
2	4200 (0)	4167 (58)	4200 (0)	4200 (0)
3	4200 (0)	4200 (0)	4200 (0)	4200 (0)
4	4200 (0)	4200 (0)	4200 (0)	4200 (0)
5	4200 (0)	4200 (0)	4200 (0)	4200 (0)

Table 3

Mean (and standard deviation) detection ranges under nighttime conditions: Unaided viewing (in feet; N=8/condition).

Wire marker*	Position lights	Anticollision lights	Searchlight	Blackout
1	125 (83)	213 (60)	1200 (112)	63 (70)
2	488 (60)	688 (60)	4200 (0)	125 (43)
3	138 (48)	213 (60)	1313 (136)	63 (48)
4	750 (71)	1163 (132)	4200 (0)	138 (48)
5	613 (78)	1225 (139)	4200 (0)	88 (33)

* (For all tables). Marker 1: Uniform sphere
Marker 2: Sphere with reflective tape
Marker 3: Uniform polyhedron
Marker 4: Polyhedron with white reflective sheeting
Marker 5: Polyhedron with yellow reflective sheeting

Table 4

Mean (and standard deviation) detection ranges under nighttime conditions: AN/PVS-5 viewing (in feet; N=4/condition).

Wire marker*	Position lights	Pinklight searchlight	Blackout
1	450 (50)	525 (109)	750 (50)
2	1250 (50)	1375 (327)	825 (163)
3	600 (48)	750 (50)	975 (286)
4	1825 (179)	1975 (268)	850 (50)
5	1975 (238)	1875 (311)	700 (71)

Table 5

Mean (and standard deviation) detection ranges under nighttime conditions: ANVIS viewing (in feet; N=4/condition).

Wire marker*	Position lights	Pinklight searchlight	Blackout
1	475 (43)	575 (83)	750 (50)
2	1425 (83)	1600 (406)	825 (43)
3	675 (109)	750 (150)	1050 (384)
4	2025 (249)	2200 (406)	950 (87)
5	2050 (269)	2250 (269)	825 (43)

* (For all tables). Marker 1: Uniform sphere
Marker 2: Sphere with reflective tape
Marker 3: Uniform polyhedron
Marker 4: Polyhedron with white reflective sheeting
Marker 5: Polyhedron with yellow reflective sheeting

Viewing performance with AN/PVS-5 and ANVIS image intensification devices are shown in Tables 4 and 5. As expected, detection ranges were greater, under comparable illumination (in this case, either with position lights [steady bright vs. dim] or under blackout conditions), with image intensification devices than without. In addition, detection ranges for each of the reflective designs were slightly longer (from 0-20 percent; average = 10 percent) with ANVIS than with the AN/PVS-5s. Estimates of the relative improvements afforded by image intensification devices over naked eye viewing and by ANVIS over AN/PVS-5s are shown for each of the markers under several lighting conditions in Appendices A-C.

As in the unaided trials, the two reflective polyhedron designs (markers 4 and 5) provided the greatest detection ranges either with position lights on (steady dim) or by direct illumination via the infrared-filtered searchlight. As before, marker 2 yielded an average detection range intermediate to those of markers 4 and 5 and the baseline designs. Detection ranges for all markers were very similar with both image intensification devices under blackout conditions. The apparent <u>improvement</u> in performance seen with the baseline designs (Markers 1 and 3) under blackout conditions may be due to an enhancement in apparent target-background contrast, i.e., improved goggle sensitivity, under "normal" ambient levels of illumination (and without compensatory adjustment of goggle output in the presence of additional sources of aircraft light).

Due to the costs and logistics associated with wire marker systems, the identification of a single design useful under all lighting and viewing conditions is desirable. Tables 6 and 7 summarize the data from which such a candidate marker may be selected.

Table 6 presents the increases in detection range among the wire markers relative to that found with the current Army design, marker 1. Because of the inability to distinguish among the designs under daylight conditions, the data are shown for nighttime trials only. For unaided viewing at night, 4200 feet (the maximum or ceiling value) was chosen arbitrarily as the range associated with the use of the searchlight for markers 2, 4, and 5.

As can be seen in Table 6, under typical aircraft lighting schemes, markers 4 and 5 were effective at ranges approximately four to six times as great as the current design, both with the naked eye and with image intensification devices. No clear-cut advantage was observed with any marker under blackout conditions. In general, the relative rankings of the designs were fairly consistent among each of the viewing and lighting conditions tested.

Table 6

Range increases (increase factors) among wire markers relative to the current Army design (marker 1).

Nighttime: Unaided				
Wire marker*	Position lights	Anticollision lights	Searchlight	Blackout
1	--	--	--	--
2	3.9	3.2	3.5	2.0
3	1.1	1.0	1.1	1.0
4	6.0	5.5	3.5	2.2
5	4.9	5.8	3.5	1.4

Nighttime: AN/PVS-5			
Wire marker	Position lights	Pinklight searchlight	Blackout
1	---	---	---
2	2.8	2.6	1.1
3	1.3	1.4	1.3
4	4.1	3.8	1.1
5	4.4	3.6	0.9

Nighttime: ANVIS			
Wire marker	Position lights	Pinklight searchlight	Blackout
1	---	---	---
2	3.0	2.8	1.1
3	1.4	1.3	1.4
4	4.3	3.8	1.3
5	4.3	3.9	1.1

* Marker 1: Uniform sphere
Marker 2: Sphere with reflective tape
Marker 3: Uniform polyhedron
Marker 4: Polyhedron with white reflective sheeting
Marker 5: Polyhedron with yellow reflective sheeting

Table 7

Summary of daytime/nighttime mean detection ranges.

Viewing condition	Detection range (ft) Wire marker* 1	2	3	4	5
Daytime	4182	4192	4200	4200	4200
Nighttime					
Unaided	400	1375	432	1563	1532
AN/PVS-5	463	1604	505	1696	1633
ANVIS	600	1283	825	1725	1708
Average nighttime	488	1421	587	1661	1624

* Marker 1: Uniform sphere
Marker 2: Uniform sphere with reflective tape
Marker 3: Uniform polyhedron
Marker 4: Polyhedron with white reflective sheeting
Market 5: Polyhedron with yellow reflective sheeting

Table 7 presents the detection range means for each marker design for each viewing condition across all lighting conditions. For the nighttime, an average of the means of the three viewing conditions also is given for each design. These data confirm the relative rankings of each of the designs and indicate the general increase in detection range afforded by the reflective polyhedrons at night.

Discussion

The selection of a wire marker for Army aviation must be one which provides the greatest detection range across all lighting and viewing conditions. For the daytime conditions, ceiling effects, caused by restricted test space (4200 foot maximum working distance), prevented discrimination between designs. Thus, only minimal differences in performance among any of the tested markers were observed. However, at a range of 4200 feet, the approximate 11.5 inch diameter of the various designs subtends an angle of about 23 arc seconds. The 1.5 and 2.5 inch pieces of reflective materials used for enhancement correspond to 3.0 and 5.0 arc seconds, respectively. It can be suggested that detection at this range is primarily a function of both shape (spherical), color (orange), and contrast (lighter object against a darker tree line) rather than specular reflection or detail within the shape. Therefore, it is unlikely that differences in detection range between any of the designs would be obtained at greater observation ranges. (However, differences in conspicuity, and, hence, detection range, could result from differences in specular reflectivity with more mobile targets or viewing from a more mobile platform.)

Three viewing systems are used for night flight, i.e., the unaided eye, the AN/PVS-5 night vision goggle, and the ANVIS. Each of these systems has a different spectral response and sensitivity. With all of these systems, the detection range of the various designs depends on the level of light, the spectral distribution of the ambient lighting, and the spectral reflective properties of the markers.

For unaided viewing in the presence of artificial lighting in the form of position and anticollision lights, the three designs using reflective material provided the greatest detection ranges with markers 4 and 5 providing nearly twice the range of marker 2. Under the increased directional output provided by the searchlight, a ceiling effect prevented discrimination between the three reflective designs -- all three designs were equally detectable out to the maximum test range of 4200 feet. Under blackout conditions, with moonlight as the principal source of illumination, detectability among designs was considerably reduced and nearly equivalent.

Similar trends in the data were observed with image intensification devices, either AN/PVS-5's or ANVIS. With the aircraft's position lights on steady dim or illuminated with the "pinklight" searchlight, detection ranges with the retroreflective polyhedrons were generally superior to the other designs. (As expected, the greater sensitivity afforded by ANVIS resulted in uniformly increased detection ranges.) Under normal low-light ambient conditions ("blackout"), no significant advantage in detectability was observed among any of the tested designs.

Recommendations

The results of this study demonstrate both viewing- and lighting-specific effects for each of the marker designs tested. While no differences among designs were observed under daylight conditions, improved performance under several viewing/lighting conditions was observed for both retroreflective polyhedrons (Markers 4 and 5) under typical aircraft lighting conditions at night. Increased detection ranges were noted both with and without image intensification devices and under aircraft lighting conditions characteristic of the local aviation training environment. It should be emphasized that, because of the benign and relatively static conditions under which the data were collected, it may be erroneous to use the ranges in the data tables as typical detection distances under training or operational conditions. Nor should these data be used in conjunction with typical airspeeds to derive putative aviator reaction times in field situations where search behavior is required. However, our data indicate that the reflective polyhedrons (markers 4 and 5) should provide relatively greater conspicuity, and hence a greater margin of operator and training safety, than designs (markers 1 and 2) currently in use.

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Appendix A.

Absolute and relative differences in detection range:
AN/PVS-5 vs. unaided viewing.

Wire marker	Position lights*		Blackout	
	Absolute difference**	Relative difference***	Absolute difference	Relative difference
1	325	3.6	687	12.0
2	762	2.6	700	6.6
3	462	4.4	912	15.6
4	1075	2.4	712	6.2
5	1362	3.2	612	8.0

* Low for AN/PVS-5; high for unaided viewing
** $Range_{[AN/PVS-5]} - Range_{[Unaided]}$
*** $Range_{[AN/PVS-5]} / Range_{[Unaided]}$

Appendix B.

Absolute and relative differences in detection range:
ANVIS vs. unaided viewing.

Wire marker	Position lights*		Blackout	
	Absolute difference**	Relative difference***	Absolute difference	Relative difference
1	350	3.8	687	12.0
2	937	2.9	700	6.6
3	537	4.9	987	16.8
4	1275	2.7	812	6.9
5	1427	3.3	737	9.4

* Low for ANVIS; high for unaided viewing

** $Range_{[ANVIS]} - Range_{[Unaided]}$

*** $Range_{[ANVIS]} / Range_{[Unaided]}$

Appendix C.

Absolute and relative differences in detection range: ANVIS vs. AN/PVS-5.

Wire marker	Position lights*		Pinklight Searchlight		Blackout	
	Abs**	Rel***	Abs	Rel	Abs	Rel
1	25	1.05	50	1.10	0	--
2	175	1.14	225	1.16	0	--
3	75	1.13	0	--	75	1.08
4	200	1.11	225	1.11	100	1.12
5	75	1.04	375	1.20	125	1.18

* Low intensity

** $\text{Range}_{[ANVIS]} - \text{Range}_{[AN/PVS-5]}$

*** $\text{Range}_{[ANVIS]} / \text{Range}_{[AN/PVS-5]}$

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